

DACA42-03-C-0024

LOGANEnergy Corp.

Campbell Hall Combined Services ROTC Building  
PEM Demonstration Program  
North Carolina Agricultural and Technological State University  
Greensboro, North Carolina  
Final Report

Exchange Membrane (PEM) Fuel Cell Demonstration  
Of Domestically Produced PEM Fuel Cells in Military Facilities

US Army Corps of Engineers  
Engineer Research and Development Center  
Construction Engineering Research Laboratory  
Broad Agency Announcement CERL-BAA-FY02

North Carolina Agricultural and Technological State University,  
Greensboro, North Carolina

November, 2004

## **Executive Summary**

LOGANEnergy Corporation has received a contract award from the US Army Corps of Engineers, Construction Engineering Research Lab to test and evaluate Proton Exchange Membrane (PEM) Fuel Cells at several DOD sites. The North Carolina A&T State University, Greensboro, NC was one of the sites awarded to LOGAN. This one year PEM demonstration has been completed after the initial start-up occurred on April 23, 2003.

The Campbell ROTC Building was chosen for the demonstration site. It hosts a 5kW, 120vac, SU-1 PEM technology demonstration unit manufactured by Plug Power Corporation, Latham, NY. The unit will operate in a grid parallel / grid synchronized configuration at 2.5kW for the one-year demonstration test program. The unit is instrumented with an external wattmeter and a gas flow meter. A phone line is connected to the power plant communication's modem to call-out with alarms or events requiring service and attention.

The Point of Contact for this project is Dr. Harmohindar Singh, Director of the Energy Research Center, (336) 334-7575.

The total estimated energy cost increase to the host site as a result in participating in this demonstration project is \$585.08.

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## **Proposal – Proton Exchange Membrane (PEM) Fuel Cell Demonstration of Domestically Produced Residential PEM Fuel Cells in Military Facilities**

### **1.0 Descriptive Title**

Campbell Hall Combined Services ROTC Building PEM Demonstration Program, North Carolina  
Agricultural and Technological State University, Greensboro, North Carolina

### **2.0 Name, Address and Related Company Information**

LOGANEnergy Corporation

1080 Holcomb Bridge Road  
BLDG 100- 175  
Roswell, GA 30076  
(770) 650- 6388

DUNS 01-562-6211  
CAGE Code 09QC3  
TIN 58-2292769

LOGANEnergy Corporation is a private Fuel Cell Energy Services company founded in 1994. LOGAN specializes in planning, developing, and maintaining fuel cell projects. In addition, the company works closely with manufacturers to implement their product commercialization strategies. Over the past decade, LOGAN has analyzed hundreds of fuel cell applications. The company has acquired technical skills and expertise by designing, installing and operating over 30 commercial and small-scale fuel cell projects totaling over 7 megawatts of power. These services have been provided to the Department of Defense, fuel cell manufacturers, utilities, and other commercial customers. Presently, LOGAN supports 30 PAFC and PEM fuel cell projects at 21 locations in 12 states, and has agreements to install 22 new projects in the US and the UK over the next 18 months.

### **3.0 Production Capability of the Manufacturer**

Plug Power manufactures a line of PEM fuel cell products at its production facility in Latham, NY. The facility produces three lines of PEM products including the 5kW GenSys5C natural gas unit, the GenSys5P LP Gas unit, and the GenCor 5kW standby power system. The current facility has the capability of manufacturing 10,000 units annually. Plug will support this project by providing remote monitoring, telephonic field support, overnight parts supply, and customer support. These services are intended to enhance the reliability and performance of the unit and achieve the highest possible customer satisfaction. Scott Wilshire is the Plug Power point of contact for this project. His phone number is 518.782.7700 ex1338, and his email address is [scott\\_wilshire@plugpower.com](mailto:scott_wilshire@plugpower.com).

### **4.0 Principal Investigator(s)**

Name	Samuel Logan, Jr.	Keith Spitznagel
Title	President	Vice President Market Engagement
Company	Logan Energy Corp.	Logan Energy Corp.
Phone	770.650.6388 x 101	860.210.8050
Fax	770.650.7317	770.650.7317
Email	<a href="mailto:samlogan@loganenergy.com">samlogan@loganenergy.com</a>	<a href="mailto:kspitznagel@loganenergy.com">kspitznagel@loganenergy.com</a>

5.0 Authorized Negotiator(s)

Name	Samuel Logan, Jr.	Keith Spitznagel
Title	President	Vice President Market Engagement
Company	Logan Energy Corp.	Logan Energy Corp.
Phone	770.650.6388 x 101	860.210.8050
Fax	770.650.7317	770.650.7317
Email	<a href="mailto:samlogan@loganenergy.com">samlogan@loganenergy.com</a>	<a href="mailto:kspitznagel@loganenergy.com">kspitznagel@loganenergy.com</a>

6.0 Past Relevant Performance Information

a) Contract: PC25 Fuel Cell Service and Maintenance Contract #X1237022

Merck & Company  
Ms. Stephanie Chapman  
Merck & Company  
Bldg 53 Northside  
Linden Ave. Gate  
Linden, NJ 07036  
(732) 594-1686

Contract: Four-year PC25 PM Services Maintenance Agreement.

In November 2002 Merck & Company issued a four-year contract to LOGAN to provide fuel cell service, maintenance and operational support for one PC25C fuel cell installed at their Rahway, NJ plant. During the contract period the power plant has operated at 94% availability. LOGAN performs the quarterly and annual service prescribed by the UTC, and performs other maintenance as required. The periods of unavailability are chiefly due to persistent inverter problems that seem to be endemic to the Toshiba power conditioning balance of the system. Field modifications and operating adjustments have largely cured the problem. Quarterly service events take 10 hours to complete with the unit under load, and the annual event takes approximately 35 hours with the unit shut down.

b) Contract: Plug Power Service and Maintenance Agreement to support one 5kWe GenSys 5C and one 5kWe GenSys 5P PEM power plant at NAS Patuxant River, MD.

Plug Power  
Mr. Scott Wilshire.  
968 Albany Shaker Rd.  
Latham, NY 12110  
(518) 782-7700 ex 1338

LOGAN performed the start-up of both units after Southern Maryland Electric Cooperative completed most of the installation work. The units are located at residential sites at Patuxant River Naval Air Station, VA and operate in standard grid connected/grid independent configurations. Both operate at 4.5kWe and have maintained 98% availability. The units, S/Ns 241 and 242 are two of the very latest GenSys models to reach the field. S/N 242 is Plug Power's first LPG fueled system to go into the field. Both have set a new level of performance expectations for this product, and are indicative of the success of the various test and evaluation programs that have been conducted over the past two years.

c) Contract: A Partners LLC Commercial Fuel Cell Project Design, Installation and 5-year service and maintenance agreement.

Contract # A Partners LLC, 12/31/01

Mr. Ron Allison  
A Partners LLC  
1171 Fulton Mall  
Fresno, CA 93721  
(559) 233-3262

On April 20, 2004 LOGAN completed the installation of a 600kWe PC25C CHP fuel cell installation in Fresno, CA. The system operating configurations allow for both grid parallel and grid independent energy service. The grid independent system is integrated with a multi unit load sharing electronics package and static switch, which initial development was funded by ERDC CERL in 1999. This is the third fuel cell installation that uses the MULS System. The thermal recovery package installed in the project includes a 100-ton chiller that captures 210 degree F thermal energy supplied by the three fuel cells to cool the first three floors of the host facility. The fuel cells also provide low-grade waste heat at 140 degrees F that furnishes thermal energy to 98 water source heat pumps located throughout the 12-story building during the winter months.

## 7.0 Host Facility Information

Since its inception as a land grant university in 1891, North Carolina Agricultural and Technical State University is a public and comprehensive university committed to fulfilling its fundamental purposes through exemplary undergraduate and graduate instruction, scholarly and creative research, and effective public service. The university offers degree programs at the baccalaureate, master's and doctoral levels with emphasis on engineering, science, technology, literature and other academic areas.

As one of North Carolina's three engineering colleges, the university offers Ph.D. programs in engineering. Basic and applied research is conducted by faculty in university centers of excellence, in inter institutional relationships, and through significant involvement with several public and private agencies. The university also conducts major research through engineering, transportation, and its extension programs in agriculture.

The Army Reserve Officers' Training Corps program at A&T is made up of a broad cross-section of college students. That's because A&T hosts Army ROTC for all colleges and universities in the greater Greensboro area. This includes, Bennet College, Guilford College, Greensboro College, and the University of North Carolina at Greensboro. Elon College is an extension center of the NCA&T Army ROTC program. Reserve Officers' Training Corps is an elective course. Its subjects include principles of management, leadership development, national defense and military history.

ASHRAE design temperatures for Greensboro, North Carolina are 96° and 7° F. Located at 886 feet above sea level North Carolina A&T averages 3,511 Heating Degree Days per year and 1,408 Cooling Degree Days.

The one story, red brick Campbell Hall Combined Services ROTC Building contains classrooms for the ROTC program.

Duke Power provides the university's electricity, and Piedmont Natural Gas is the fuel provider.



## 8.0 Fuel Cell Installation

In December 2002, the Campbell Hall Combined Services ROTC Building at North Carolina Agricultural and Technological State University site was awarded to LOGAN, and the installation began in late February 2003. [Figure 1](#) and [Figure 2](#) are photos of the fuel cell on its pad at the Campbell Hall ROTC building.

The site provides a significant opportunity for the program, as it places an operating PEM fuel cell on a major southern university operating on a commercial grid system owned by Duke Power. The installation site occupies a very visible presence in a green space between the ROTC building and a student cafeteria. Piedmont Natural Gas installed a 300-foot natural gas line to supply gas to the fuel cell.



Figure 1

Figure 2



In Figure 2 above, another view of the installation shows the fuel cell against a backdrop of the Campbell Hall ROTC Building. The fuel cell was rigged onto the pad with the assistance of a commercial fork truck. The mechanical room is conveniently located behind the adjacent brick wall. The photo also shows the natural gas meter at left and the electrical interface at right.

LOGAN contacted the North Carolina Department of Health and Natural Resources to inquire of the need to apply for an air quality permit to operate the fuel cell. Since the unit's emissions are less than 5 tons per year it qualified for the small generator exemption under in accordance with North Carolina Code 2Q.0102Cq (e).

In addition LOGAN met with representatives of Duke Power to determine whether they would require any special safety equipment or other safety testing prior to beginning operations with the fuel cell. After a review of the fuel cell system, and in consideration of its very minor impact on the campus electrical distribution system, Duke had no objections to the installation plan.

The installation tasks were completed on April 23 and the initial start of the NC A&T unit was on April 28, 2003, requiring a total of 155 man-hours to complete installation and commissioning.

## NC A&T Installation Line Diagram

### Campbell Hall ROTC Center

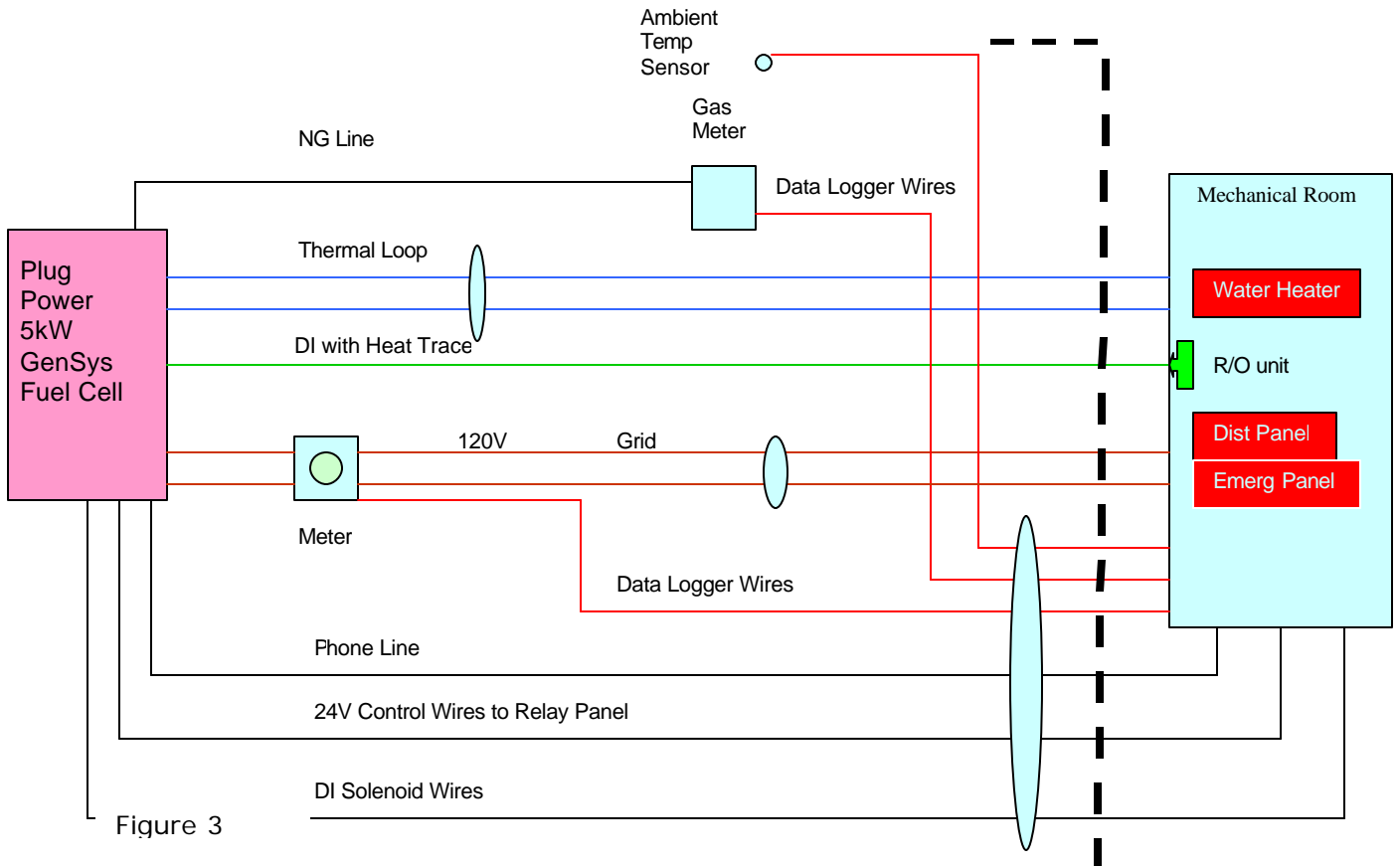


Figure 3

Figure 3, above, diagrams the fuel cell installation with utility interfaces including, power and water in the adjacent mechanical room of Campbell Hall.

#### 9.0 Electrical System

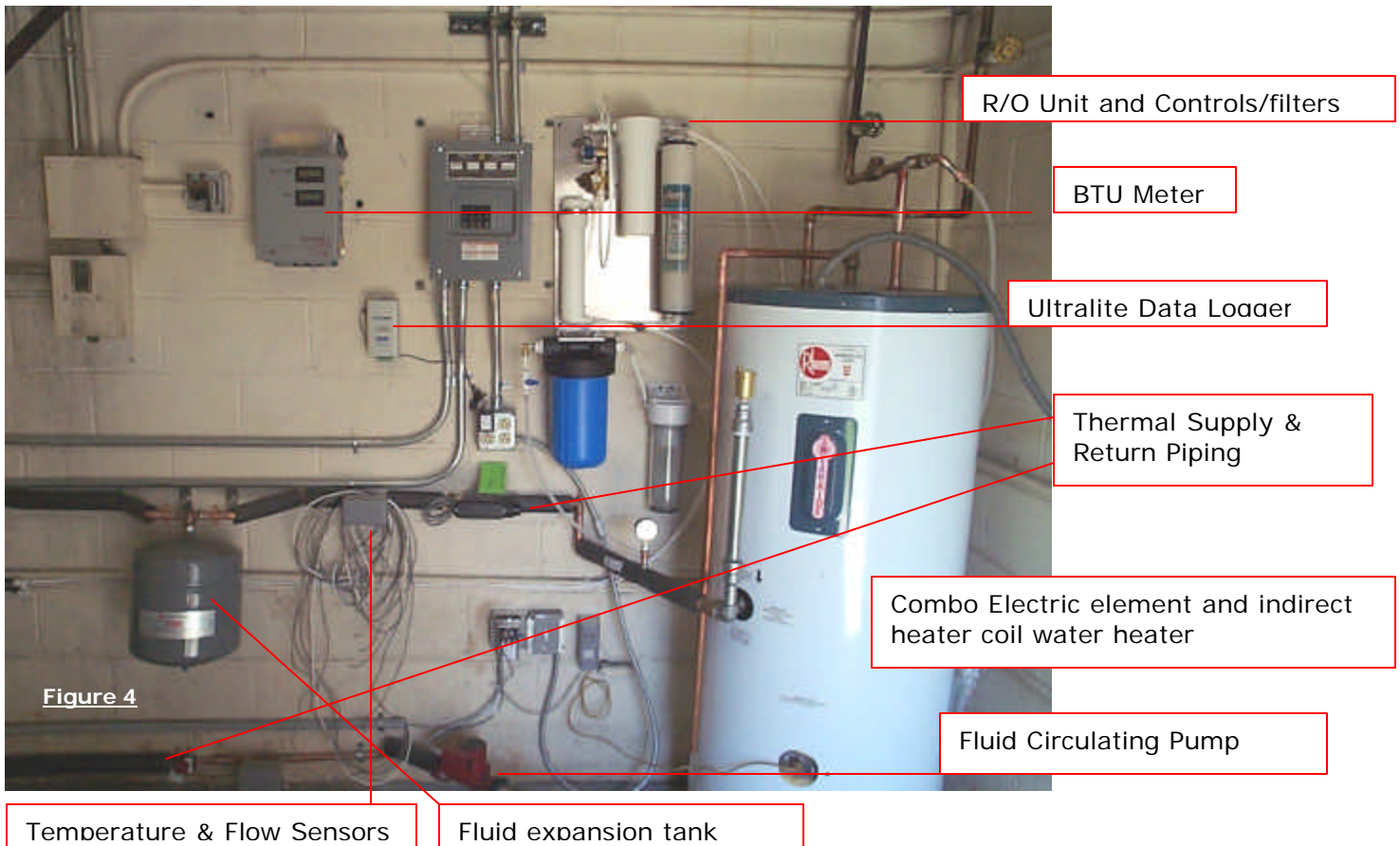
The fuel cell inverter has a power output of 110/120 VAC at 60 Hz, matching the home's power distribution panel with its connected loads at 110/120 VAC. The installation includes both a grid parallel and a grid independent configuration. This is possible because this unit has Plug Power's new MP5 inverter that enables the dual service configuration. The fuel cell provides stand-by power to a new 100amp critical circuit panel that serves plug loads and other convenience outlets in the classrooms.

To do this, LOGAN installed two 120vac wire conductors from the fuel cell to a dual pole meter then to a dual pole service disconnect. The dual pole wattmeter is able to record separately the kW demand on each conductor. From the dual pole service disconnect the conductors split off in two directions. The grid parallel conductor terminates at the main service panel in the residence and the grid independent conductor terminates at the new emergency load panel. Some ordinary kitchen loads supplied by convenience outlets are the circuits, approximately 20 amps of service that were moved to the emergency to simulate the application. The line diagram seen in

Figure 3 above, identifies the methods and the individual components that LOGAN used at the site to accomplish this.

#### 10.0 Thermal Recovery System

Figure 4, below, is a photo of the equipment and instrumentation installed to support the thermal recovery plan.



The thermal recovery system is designed to try to optimize the installation benefits to the host by capturing waste heat from the fuel cell and transferring it the building's thermal loads. The GenSys5C fuel cell incorporates a customer heat exchanger that rejects process heat to either an air-cooled radiator or to a waste heat loop. While operating at a set point of 2.5 kWh, the fuel cell provides 7800 Btuh to the storage tank at approximately 140 degrees F. The current design being tested at North Carolina A&T represents both a design and cost improvement over LOGAN's first CHP installation at Fort Jackson in South Carolina. In this case, the waste heat circulates between the fuel cell and a new hot water tank installed by LOGAN that is a combination electric/indirect heat coil unit manufactured by Rheem. It replaces a old discarded electric hot water heater. Figure 4 is a photo of the thermal recovery components including the location of an Onicon BTU meter, circulating pump and the hot water storage tank. The small pump, pictured above, circulates a glycol solution between the fuel cell and the hot water tank transferring the fuel cell's waste heat into the tank as it flows through the coils wrapped circumferentially around the tank.

The BTU meter provides a continuous output of heat transferred into the thermal recovery system.

While the thermal recovery system worked as designed, thermal utilization was very limited due to the lack of demand for hot water in the classroom building.

The external thermal recovery loop on Plug Power GenSys fuel cells should be designed to meet the following specifications:

- Flow: 0-10 gpm (1-2 gpm will maximize heat reclamation from the fuel cell)
- Pressure:  $\leq 30$  psig
- Temperature: (installation specific) with a flow rate of 1-2 gpm, the return temperature to the customer-supplied system will be approximately 140°F
- Available heat:
  - 11,200 BTU/hr @ 2.5kWe
  - 21,900 BTU/hr @ 4.0kWe
  - 27,000 BTU/hr @ 5.0kWe

## 11.0 Data Acquisition System

During the period October 2002 to August 2003, LOGAN's field service technicians performed their tasks with the support of a very rudimentary SCADA system developed by Plug Power for communicating with deployed units. This system provided one-way communication from each unit to Plug's customer support center, allowing the unit to call in overnight to download a data package and an operating status report. However, LOGAN realized very quickly that the system was inadequate and unreliable to provide the high level of communications support needed for its wide-ranging PEM demonstration program. At times a unit called in and provided only partial data or incorrect data. This created uncertainty in troubleshooting and further delay in restoring units to service. On other occasions a unit might fail to call in for a week or more frustrating the normal chain of events leading to a service advisory. While much can be said about the early learning curve experience in developing service norms, the weakness of the SCADA system became a major source of dissatisfaction with Plug Power. Under the circumstances the only means of determining a unit's actual status was to make a service call to the site. However, the scope of LOGAN's PEM program required a better solution. Finally, in March 2003 an event occurred that gave Plug direct insight into the shortcomings of its SCADA system. After advising of a shutdown at Fort Bragg, Plug sent its own technician to the site because LOGAN's technicians were servicing other units. The technician flew from Albany, New York to Raleigh, North Carolina and then drove out to the site. Upon arriving, the technician discovered that the unit was operating normally. Indeed the SCADA system was not.

This event was an important turning point for the LOGAN/Plug Power relationship and its cooperative efforts in achieving the goals of the PEM Demonstration Program. Six weeks later in early June, six representatives from LOGAN and eight from Plug Power met in Atlanta for two days of forthright discussions. The meeting focused on short-term methods and longer term solutions to improve remote PEM fuel cell performance. Most significantly Plug determined that it would institute immediate software changes and upgrades to insure the accuracy of fuel cell data communications. Plug also promised to initiate a design change to its SCADA system that would permit bi-directional remote communications with the fuel cell controller. More importantly Plug promised that LOGAN's technicians would be able to remotely troubleshoot, change set points and attempt restarts under some circumstances. Lastly they also promised that they would publish a daily status report covering all of LOGAN's units. By early August Plug began sending daily status reports, and by mid September Plug shipped LOGAN's technician's new control software that permits remote diagnostics, monitoring, troubleshooting, and restart capabilities. Since the introduction of this new service capability along with the adoption of improved service

techniques to go with it, fleet performance, availability and operating costs have begun to show positive new trends.

An Ultralite Logger pictured above in Figure 4 records and stores inputs from the wattmeter, gas meter, Btu meter and an ambient temperature probe. A phone connection to the unit permits remote data retrieval.

## 12.0 Fuel Supply System

Since natural gas was not immediately available to Campbell Hall, Piedmont Natural Gas of North Carolina provided matching funds of \$10,500 to run a natural gas supply line approximately 300 feet to supply the fuel cell. After Piedmont stubbed the natural gas supply at the fuel cell pad, LOGAN installed a gas meter adjacent to the fuel cell pad as indicated in Figure 3 and seen in Figures 1 and 2. A regulator at the fuel cell gas inlet maintains the correct operating pressure at 10-14 inches water column.

The Plug Power PEM fuel cell natural gas requirements are:

- Must be >90% methane
- No greater than 15 ppm sulfur on a yearly average basis
- Supply Pressure: 4" to 11" water column
- Maximum flow rate: 105,000 btu/hr
- Nominal flow rate: 72,700 btu/hr

### 13.0 Program Costs

Estimated Vs. Actual

#### North Carolina Agricultural and Technological State University

Project Utility Rates			
1) Water (per 1,000 gallons)		\$2.07	
2) Utility (per KWH)		\$0.0350	
3) Natural Gas ( per MCF)		\$6.03	
First Cost		Estimated	Actual
Plug Power 5 kW GenSys5C		\$ 65,000.00	\$ 65,000.00
Shipping		\$ 1,800.00	\$ 425.00
Installation electrical		\$ 4,200.00	\$ 4,400.00
Installation mechanical & thermal		\$ 6,400.00	\$ 6,710.00
Watt Meter, Instrumentation, Web Package		\$ 3,150.00	\$ 4,454.00
Site Prep, labor materials		\$ 925.00	\$ 925.00
Technical Supervision/Start-up		\$ 8,500.00	\$ 13,950.00
Total		<b>\$ 89,975.00</b>	<b>\$ 95,864.00</b>
Assume Five Year Simple Payback		\$ 17,995.00	\$ 19,172.80
Forecast Operating Expenses	Volume	\$/Hr	\$/ Yr
Natural Gas Mcf/ hr @ 2.5kW	0.0328	\$ 0.20	\$ 1,561.14
Water Gallons per Year	14,016		\$ 29.01
Total Annual Operating Cost			\$ 1,590.15
Economic Summary			
Forecast Annual kWh		19710	
Annual Cost of Operating Power Plant		\$ 0.081 kWh	
Credit Annual Thermal Recovery		\$ (0.016) kWh	
Project Net Operating Cost		\$ 0.065 kWh	
Displaced Utility cost		\$ 0.035 kWh	
Energy Savings (Increase)		(\$0.030) kWh	
Annual Energy Savings (Increase)		(\$585.08)	

#### Explanation of Calculations:

**Actual First Cost Total** is a *sum* of all the listed first cost components.

**Assumed Five Year Simple Payback** is the Estimated First Cost Total *divided by* 5 years.

#### Forecast Operating Expenses:

Natural gas usage in a fuel cell system set at 2.5 kW will consume 0.033 Mcf per hour. The cost per hour is 0.033 Mcf per hour x the cost of natural gas to NCA&T per Mcf at \$6.03. The cost per year at \$1561.14 is the cost per hour at \$0.20 x 8760 hours per year x 0.9. The 0.9 is for 90% availability.

Natural gas fuel cell systems set at 2.5 kW will consume 1.6 gallons of water per hour through the DI panel. The total volume of water consumed at 14,016 gallons per year is 1.6 gph x 8760 hours per year. The cost per year at \$29.01 is 14,016 gph x cost of water to NCA&T at \$2.07 per 1000 gallons.

The Total Annual Operating Cost, \$1590.15 is the *sum* of the cost per year for the natural gas and the cost per year for the water consumption.

#### **Economic Summary:**

The Forecast Annual kWh at 19,710 kWh is the product of 2.5 kW set point for the fuel cell system x 8760 hours per year x 0.9. The 0.9 is for 90% availability.

The Annual Cost of Operating the Power Plant at \$0.081 per kWh is the Total Annual Operating Cost at \$1590.15 *divided by* the forecast annual kWh at 19,710 kWh.

The Credit for Annual Thermal Recovery of \$0.018/kWh equals 7800 BTU per hour thermal recovery at 2.5 kW *divided by* 3414BTU/kWh *multiplied* .20 recovery factor, *multiplied by* \$0.0350/kWh. As a credit to the cost summary, the value is expressed as a negative number.

The Project Net Operating Cost is the *sum* of the Annual Cost of Operating the Power Plant *plus* the Credit Annual Thermal Recovery.

The Project Net Operating Cost is the *sum* of the Annual Cost of Operating the Power Plant *plus* the Credit Annual Thermal Recovery.

The Displaced Utility Cost is the kWh cost of electricity to the site.

**Energy Savings (increase)** equals the Displaced Utility Cost *minus* the Project Net Operating Cost.

**Annual Energy Savings (increase)** equals the Energy Savings x the Forecast Annual kWh.

#### 14.0 Milestones/Improvements

The GenSys Residential PEM fuel cell at North Carolina A&T was placed on its pad in March, 2003. The first successful eight hour run of the fuel cell took place on April 28, 2003. This power plant experienced six unplanned shutdowns during the 12 month demonstration. The fuel cell had three planned shutdowns during the demonstration. Between October 22, 2003 and the end of the demonstration, a period of 189 days, the fuel cell did not have any unplanned shutdowns. The last planned shutdown for this fuel cell was on January 21, 2004. Between January 21, 2004 and the end of the demonstration, a period of 98 days, there were no shutdowns of any kind. The fuel cell demonstration was successfully completed on April 28, 2004

Over the course of the 12 month demonstration the fuel cell was available 91.6% of the time. To date, this is the highest availability attained by any PEM fuel cell installed by LOGANEnergy. This improvement can be attributed to improvements in the fuel cell design by Plug Power and improved maintenance expertise on the part of LOGANEnergy field technicians.

#### 15.0 Decommissioning/Removal/Site Restoration

The Demonstration program for unit 190 ended on April 28, 2004. At the request of Dr. Harmohindar Singh at the North Carolina A&T Energy Research Center this unit was not decommissioned. It was left at the site and is now being operated by the Energy Research Center.

#### 16.0 Additional Research/Analysis

On June 9, 2004 a Harmonic Meter was used to measure the harmonics of the existing electrical system at the Campbell Hall both with the fuel cell connected and with the fuel cell disconnected. The measurements from this test are attached in Appendix 3. (Harmonic readings are proprietary).

## 17.0 Conclusions/Summary

The PEM fuel cell demonstration at North Carolina A&T did not encounter any insurmountable problems. Indeed, the last six months of the program the unit operated virtually problem free. The test period concluded with a total 7928 fuel cell load hours, 19,609 kWh of electricity generated and achieved an overall availability of 91.6%.

Non fuel cell related problems continue to impact overall availability. A November 25, 2003 shutdown was caused by lack of fuel when a nearby construction crew accidentally cut the natural gas line to the fuel cell.

The lessons learned at this site from the installation experience and responding to the six unplanned shutdowns will transfer well to other projects served by LOGAN, Plug Power and CERL. In addition, the experience has been a forceful contribution to greater fuel cell awareness at the University and within the local community, as well as the broader objectives of the fuel cell industry and product commercialization.

## **Appendix**

- 1) Monthly Performance Data
- 2) Work Logs
- 3) Installation Acceptance Test
- 4) Harmonics Test